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USE OF AN AIR-ASSISTED FUEL NOZZLE TO REDUCE IDLE EMISSIONS OF A JT8D ENGINE COMBUSTOR

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16. Abstract

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SUMMARY

Tests were performed at typical engine idle conditions on a single-can JT8D combustor to evaluate the effect of an air-assisted fuel nozzle on reducing exhaust emissions. The combustor was installed in a 24 centimeter (9.45 in.) housing in a connected-duct test facility; an existing instrumentation section, not specifically designed for JT8D combustor dimensions, was utilized for comparative emission measurements. By injecting high-pressure air through the secondary-flow passage of the standard duplex fuel nozzle, it was possible to reduce hydrocarbon emissions from 840 parts per million to 95 parts per million and carbon monoxide emissions from 873 parts per million to 258 parts per million. NO_x emissions increased slightly from 18 parts per million to 22 parts per million. An air-assist differential pressure of only 20.1 newtons per square centimeter (29.1 psi) and an airflow rate of only 0.22 percent of the total combustor airflow was required.

INTRODUCTION

An investigation was conducted to determine the feasibility of converting the conventional duplex fuel nozzle of the JT8D combustor to an air-assisted fuel nozzle to provide a simple means of reducing combustion emissions at idle.

The proposed 1979 regulations of the Environmental Protection Agency limit the levels of emissions at idle. Meeting these regulations will be a difficult task. Ultimately, changes in the design of the combustor may be required.

The use of an air assist fuel nozzle has been shown to be a way of reducing combustion emissions at idle. In reference 1 the conventional duplex fuel nozzles of a J-57 combustor were converted to air-assisted nozzles for engine idle operation. This was possible because during idle only the primary nozzle is flowing fuel. The secondary

nozzle, normally used during high power operation is not active during idle operation and air can, therefore, be injected through this nozzle. The injected air serves to finely atomize the fuel resulting in more complete combustion, hence lower emitted levels of CO and THC. In practice this could be accomplished by bleeding a small quantity of air from the compressor exit, supercharging it and then injecting it through the secondary fuel nozzle. At higher power levels, the airflow and supercharger are valved out of the fuel system.

The amount of injected air required to cause a significant change in emissions is very small. In reference 1, an airflow rate of less than 0.5 percent of the total engine airflow at a supercharged pressure ratio of 4 decreased THC emissions by 69 percent and CO emissions by 20 percent.

These tests were conducted on a typical JT8D engine combustor can and fuel nozzle to detérmine what improvement in idle emission might be expected by using the air-assist approach. The JT8D combustor was chosen for this investigation because a major retrofit involving the installation of a new fan is being considered for this engine. The air-assist nozzle conversion, if successful in substantially reducing idle emissions could become a part of the JT8D engine retrofit. All tests were conducted at the specified engine idle operating conditions. No attempts were made to improve idle emissions by any other means. ASTM-Jet A fuel was used for all tests.

APPARATUS AND PROCEDURE

The test facility is shown schematically in figure 1. This is a connected-duct combustor test facility with inlet-air temperature, pressure and airflow rates all independently variable. The JT8D combustor can was installed in a modified test housing as shown in figure 2. The instrumentation and gas analysis sampling probe locations are noted on this figure. This test facility, while not ideally matched to the size of the JT8D combustor was used to expedite the test program. The facility had been used to determine odor characteristics of the exhaust gases from a J57 combustor as described in reference 2. An insert 24 centimeters (9.45 in.) in diameter was installed to reduce the reference area to a value typical for the JT8D combustor as installed in an engine.

Gas Sampling and Analysis

The exhaust emission sampling probe is shown in figure 3. Gases collected by eight such probes were passed through steam-heated lines to the gas analysis instruments shown in figure 4. Unburned hydrocarbon concentrations were measured with a flame-ionization detector, CO and CO_2 concentrations were measured with NDIR instru-

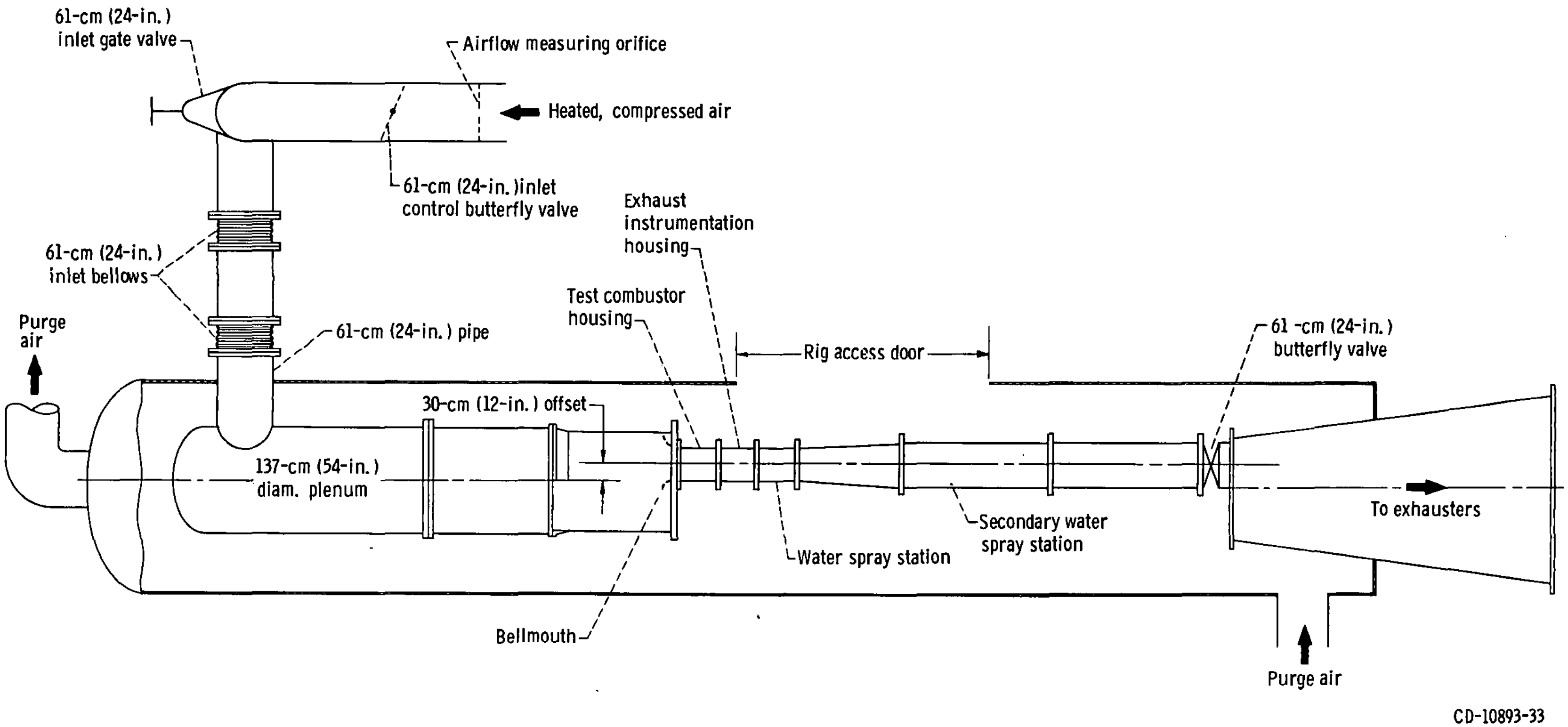
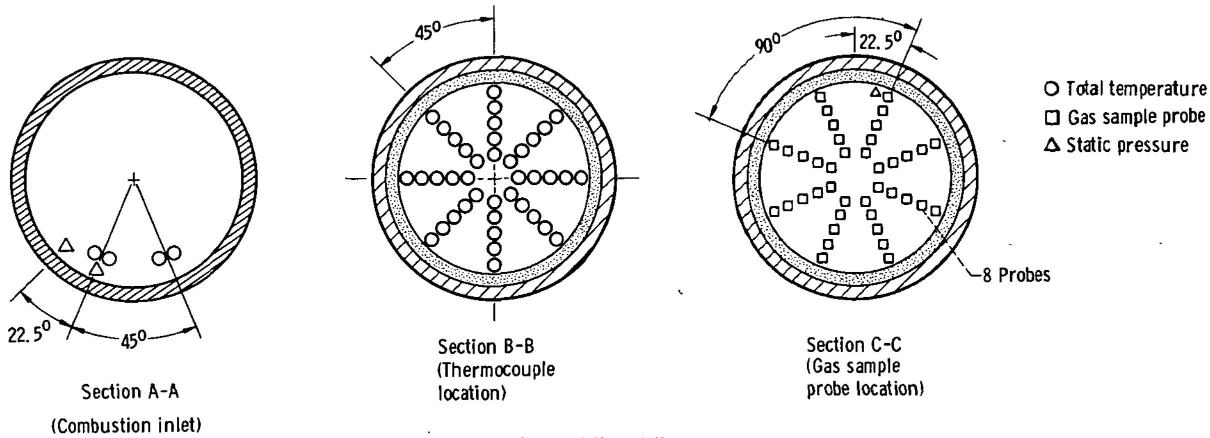
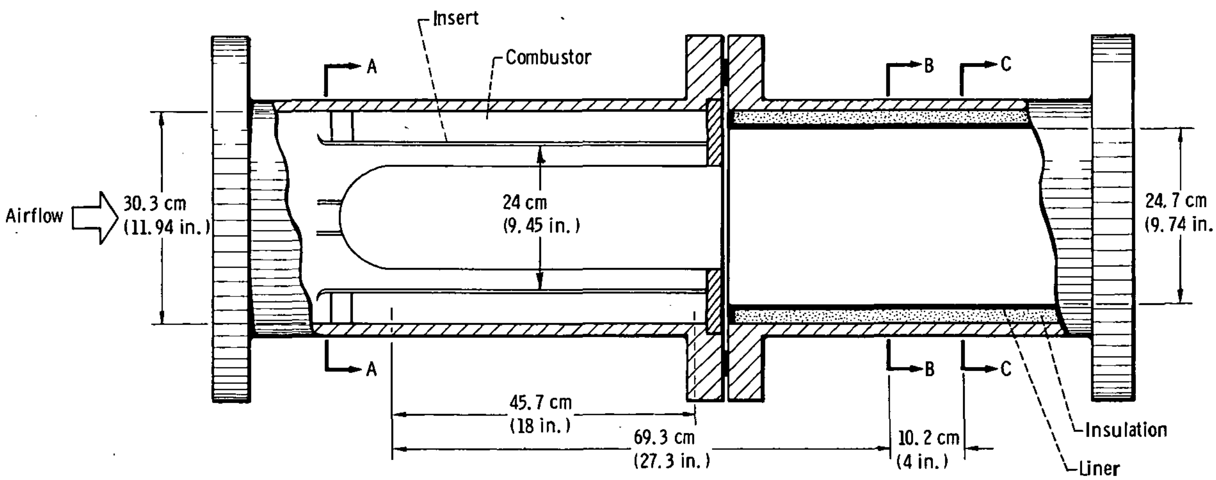


Figure 1. - Test installation.



(a) Instrumentation stations.



(b) Location of instrumentation at each station.

Figure 2. - Combustor test duct.

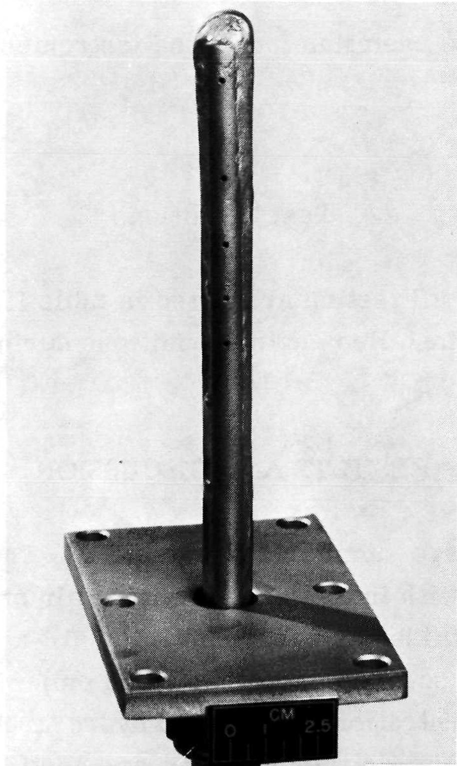


Figure 3. - Five-point steam-cooled exhaust emission probe.

Figure 4. - Gas analysis equipment.

ments and NO and NO_x with a chemiluminescence instrument equipped with a thermal converter (ref. 3).

Test Conditions

The test conditions for all testing are listed in table I. These test conditions are representative of the actual installed engine conditions during ground idle.

RESULTS AND DISCUSSION

The test data obtained are summarized in table II. The variations of the concentrations of CO, THC, and NO_x with increasing atomizing air pressure are shown in figure 5. No significant reduction in emissions occurs until the air-assist differential pressure exceeds about 7 newtons per square centimeter (10.2 psi). Beyond that value, there is a rapid decrease in the concentration of unburned hydrocarbons and carbon monoxide. At a differential pressure of 20.1 newtons per square centimeter (29.1 psi) the concentration of unburned hydrocarbons has been reduced approximately 88 percent and the concentration of CO approximately 70 percent. There was a slight increase in the level of NO_x emissions, from 17 to 22 parts per million.

Some further reduction in emissions levels of THC and CO might be expected at still greater atomizing air pressures. However, it seems apparent that these changes might be small and are probably not justifiable when weighed against the increased pressure ratio required of the supercharger. No differential pressures greater than those shown were used in this effort; reference 1 clearly indicates that the gains achieved by increasing supercharger pressure ratios above a value of four are insignificant.

The air-assisted flow rate at a pressure differential of 20.1 newtons per square centimeter (29.1 psi) was calculated to be 0.0030 kilogram per second (0.0066 lb/sec) or approximately 0.22 percent of the combustor airflow rate.

Because the exhaust instrumentation section was not designed specifically for the JT8D geometry, no attempt was made to compute emission index values or to relate these measured changes in emissions to actual changes in combustion efficiency. However, these tests do indicate that this air-assisted nozzle conversion has the potential to make a significant reduction in JT8D engine idle emissions.

TABLE I. - JT8D IDLE OPERATING CONDITIONS

Airflow rate, kg/sec (lb/sec)	1.35 (2.98)
Inlet air temperature, K (^{o}F)	382 (228)
Inlet air pressure, N/cm^2 (psi)	24.0 (34.8)
Fuel-air ratio	0.0112

TABLE II. - TEST RESULTS

[Combustor inlet temperature, 382 K (228^{o} F); combustor inlet pressure, 24.2 N/cm^2 (35.1 psi); airflow, 1.37 kg/sec (3.01 lb/sec).]

Fuel-air ratio	Combustor exit temperature		Exhaust emissions, ppm			Primary nozzle (fuel) pressure differential		Secondary nozzle (air) pressure differential	
	K	^{o}F	Hydro-carbons	Carbon monoxide	Oxides of nitrogen NO_x	N/cm^2	psi	N/cm^2	psi
0.0115	782	948	840	873	17.9	110.1	159.7	0	0
.0112	796	973	95	258	22.3	107.6	156.1	20.1	29.1
.0114	790	963	289	455	19.3	106.1	153.9	11.7	16.9
.0113	797	975	124	307	21.5	104.7	151.9	15.6	22.7
.0112	778	941	763	886	16.7	103.9	150.7	5.8	8.4
.0112	780	944	785	869	16.6	103.4	149.9	0	0
.0112	780	944	785	871	16.6	103.0	149.4	0	0

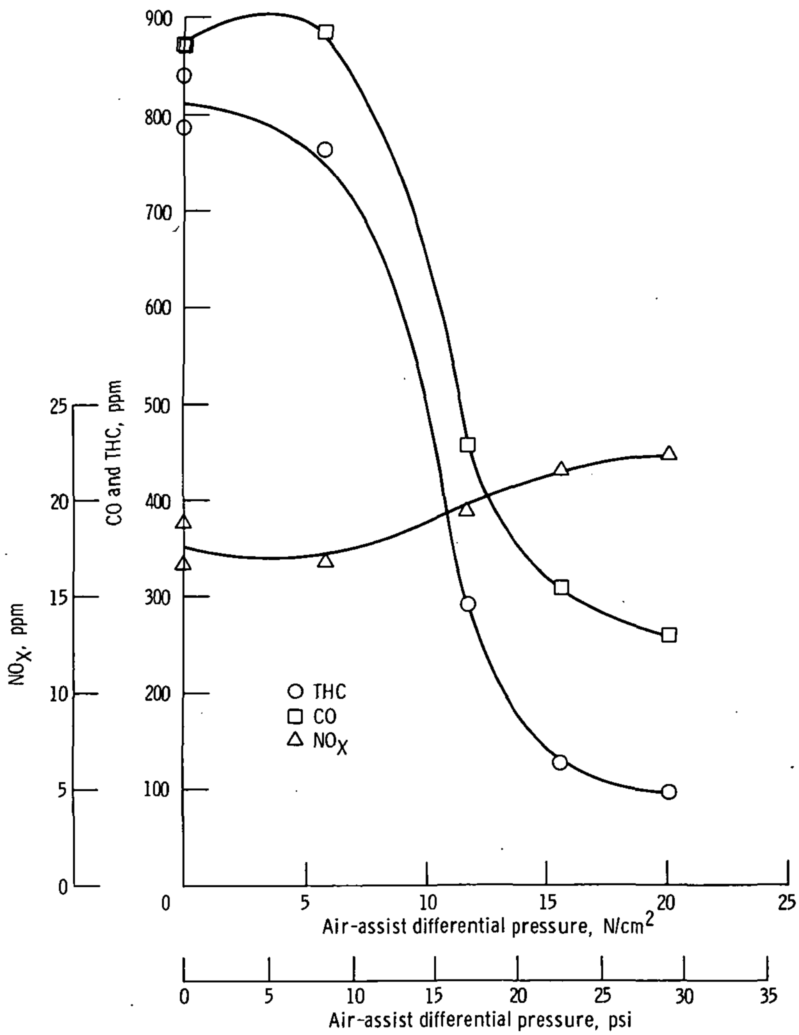


Figure 5. - Variation of idle emissions with air-assisted nozzle differential pressure. Combustor inlet temperature, 382 K (228^0 F); combustor inlet pressure, 24.2 newtons per square centimeter (35.1 psi); airflow, 1.37 kilograms per second (3.01 lb/sec); fuel-air ratio, 0.0113.

SUMMARY OF RESULTS

A test program to evaluate the potential of an air-assist fuel nozzle conversion for reduction of idle emissions of a JT8D combustor produced the following results:

At an air-assisted nozzle pressure differential of 20.1 newtons per square centimeter (29.1 psi) unburned hydrocarbon levels in the exhaust were reduced by 88 percent and CO levels were reduced by 70 percent of the values with no air-assisted fuel atomization. An airflow rate of only 0.22 percent of the total combustor air flow was required to achieve these levels of emissions reduction.

Lewis Research Center
National Aeronautics and Space Administration,
Cleveland, Ohio, August 21, 1973,
501-24.

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